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Effects of Fertilizer on Stem Rot of Rice

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CONTENTS

	Page
Experimental methods and results	4
Field experiments	4
Greenhouse studies	12
Conclusion	15
Literature	17

EFFECTS OF FERTILIZER ON STEM ROT OF RICE

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Stem rot of rice was described first in Italy in 1876 by Cattaneo *(1)*. Since then the disease has been reported from numerous rice-producing countries, including the United States, China, Japan, Bulgaria, India, Ceylon, Cochin China, Portugal, and the Philippine Islands. In the United States, although stem rot has been reported from all of the principal rice-producing states (Texas, Louisiana, Arkansas, and California), Arkansas is the only state in which the disease has important economic effects. An estimate of the losses resulting from the disease and a description of the symptoms of the disease have been given in previous bulletins *(2, 9, 10)*. Obviously, the disease is not equally important in the foreign countries from which it has been reported. Mundkur *(4)*, after studying the parasitism of the disease in India, found that *Sclerotium oryzae* failed to bring about the disease in pots and fields heavily infested with sclerotia, while Reyes *(6)*, working on the disease in the Philippine Islands, found the disease destructive and widespread.

A number of workers, concerned with stem-rot control, have offered remedial measures, such as lime applications, destruction of diseased plants, and rotation; however, none of the measures have proved satisfactory in Arkansas. Consequently, new measures for the prevention or amelioration of the disease have been sought. The purpose of this bulletin is to present the results of greenhouse and field experiments on the relation of the host nutrition to the development of the disease.

The experiments were initiated when it was observed that losses, caused by the disease, are affected by the type of growth of the host plant. In numerous instances heavy losses resulting from poorly filled panicles and lodging were noticed when the rice was rank and succulent. Losses were especially great when rank-growing rice had weak culms, resulting from a thick stand of rice. Furthermore, in the severely infested plots at the Rice Branch Experiment Station, as well as in a number of fields kept under observation for several years, there was a tendency for stem rot to decrease rather than increase in severity as the rice became less vigorous as a result of the continuous cropping system employed.

The need for additional information on host nutrition seemed even more apparent when stem-rot observations were made on rice fertilizer experiments in progress at the Rice Branch Experiment Station. In one experiment ammonium sulphate, superphosphate, and muriate of potash had been applied alone, and in various combinations, to a dry-land crop, which was followed the succeeding year by rice. It appeared that potassium, when applied alone or in combination with nitrogen and phosphorus, had a retarding effect upon the development of the stem-rot disease. In another experiment the rice crop had been fertilized with ammonium sulphate, superphosphate, potassium sulphate, and ammophosko. Stem rot was less severe in the plots receiving potassium than in the plots receiving nitrogen and phosphorus.

Very little work on the effects of fertilizer on stem rot has been done. Sakurai *(7)* suggested the application of wood ashes or lime for the control of stem rot. Reyes *(6)* reported that nitrogenous fertilizers are conducive to the rapid development of stem rot. Nakata *(5)*[1] warned against the excessive use of nitrogenous fertilizers when the three basic fertilizers are applied.

The fungus causing stem rot has a sclerotial stage, originally described as *Sclerotium oryzae* Catt.; a conidial stage, originally described as *Helminthosporium sigmoideum* Cav. *(8)*; and a perfect stage, *Leptosphaeria salvinii* Catt. *(8)*. A weakly virulent variety of *H. sigmoideum*, namely *H. sigmoideum irregulare*, has also been described *(3)*. *L. salvinii* was used in the greenhouse experiments, while in the field plots the sclerotia of this virulent variety greatly predominated. The results of experiments on the importance of the conidia, ascospores, and sclerotia in the production of disease indicate that the sclerotia cause the major part of the infections.

Experimental Methods and Results

Field experiments. The field experiments were designed primarily to test, over a period of years, the effect of various fertilizer combinations on the development of stem rot. Since the designs of the experiments, as well as the amount, manner, and time of applications, varied somewhat from year to year, the experimental methods will be given in connection with the presentation of results. Most of the experiments were conducted at the Rice Branch Station on plots on which rice had been grown 19

[1] Portions of the text dealing with the sclerotial diseases of rice were translated by Saburo Katsura.

TABLE 1. EFFECT OF FERTILIZERS ON STEM-ROT SEVERITY AND YIELD OF EARLY PROLIFIC RICE AT RICE BRANCH EXPERIMENT STATION, 1936

Treatment [1]	Rate of application per acre	Stem rot index [2]	Acre yield	Treatment [3]	Rate of application per acre	Stem rot index [2]	Acre yield
	Pounds		*Bushels* [4]		*Pounds*		*Bushels* [4]
Sodium nitrate	500	40	71	Ammonium sulphate	250	25	54
Superphosphate	500	21	65	Superphosphate	250	16	58
Potassium chloride	500	13	49	Muriate of potash	250	17	46
Sodium nitrate Superphosphate	500 500	38	75	Ammonium sulphate Superphosphate	250 250	....	52
Sodium nitrate Potassium chloride	500 500	19	60	Ammonium sulphate Muriate of potash	250 250	13	57
Superphosphate Potassium chloride	500 500	21	65	Superphosphate Muriate of potash	250 250	19	57
Sodium nitrate Superphosphate Potassium chloride	500 500 500	23	60	Ammonium sulphate Superphosphate Muriate of potash	250 250 250	15	60
Check	0	31	43	No treatment	0	17	46

[1] Applied July 17, 1936. [2] Average of five replicates. [3] Applied August 10, 1936. [4] Average of five replicates.

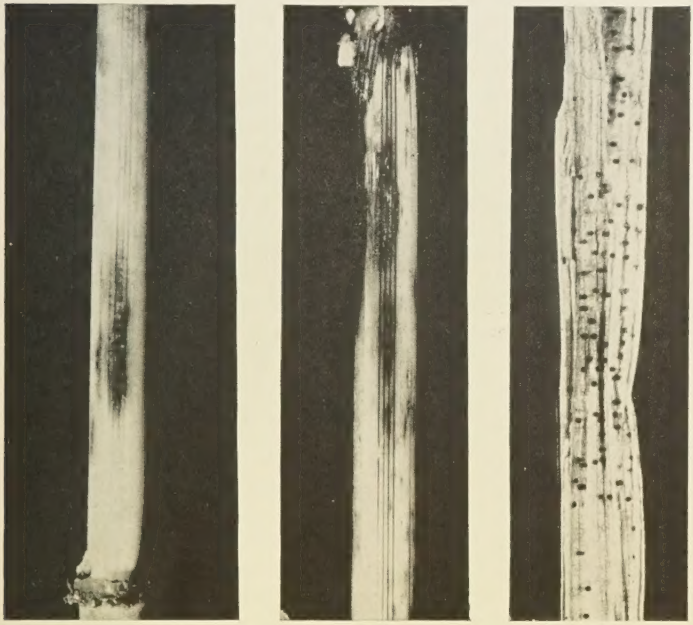
years out of the preceding 24-year period. The plots were known to be infested with the sclerotial stage of the fungus; however, in order to insure more uniform results, infested rice stubble was scattered over the plots after the rice was sown. The rice was sown each year as near the middle of May as weather conditions would permit. With the exception of the two preliminary experiments, presented in Tables 1 and 2, the experimental design known as randomized blocks was used.

TABLE 2. EFFECT OF FERTILIZERS ON INCIDENCE OF STEM ROT AND YIELD OF EARLY PROLIFIC RICE WHEN APPLIED ON JULY 9 AND JULY 28, RICE BRANCH EXPERIMENT STATION, 1937

Treatment	Rate per acre	July 9 application		July 28 application	
		Stem-rot index [1]	Acre yields [1]	Stem-rot index [1]	Acre yields [1]
	Pounds		*Bushels*		*Bushels*
Ammonium sulphate	90	12.2	30.17	14.6	31.26
Ammonium sulphate	180	12.4	31.10	14.0	30.98
Superphosphate	300	8.2	25.10	12.1	27.57
Potassium sulphate	72	7.8	27.27	7.6	23.65
Ammonium sulphate Superphosphate	180 300	37.0	33.80	17.3	30.17
Ammonium sulphate Potassium sulphate	180 72	15.4	25.76	13.8	28.75
Superphosphate Potassium sulphate	300 72	11.6	26.44	14.8	30.58
Ammonium sulphate Superphosphate Potassium sulphate	180 300 72	14.0	32.20	12.8	36.78
Ammonium sulphate Superphosphate Potassium sulphate	90 150 36	12.1	35.62	7.7	30.80
Check	0	8.0	27.98	10.3	31.74

[1] Average of five replicates.

Each year the stem-rot data were taken at the same time; that is, when the rice was ready to harvest. In order to present a more critical comparison of the different treatments, the final results are given in terms of index values. To obtain these values, 50 plants, picked at random from each replicate, were divided into five classes, namely, (1) plants healthy, (2) plants with only diseased sheaths, (3) plants with lightly diseased culms (Figure 1-A), (4) plants with moderately diseased culms (Figure 1-B), and (5) plants with severely diseased culms (Figure 1-C). After



A B C

Figure 1. Supreme Blue Rose rice culms showing progressive stages in the development of stem rot. A = early stage, ×1; B = medium stage, ×1; C = late stage, ×2.

the plants were classified, the disease indices were obtained by dividing the products, which were obtained by multiplying the number of plants in classes 2, 3, 4, and 5 by 25, 50, 75, and 100, respectively, by the total number of plants in the five classes. Thus, a high index value represents severe stem-rot infection.

In the first experiment, the set-up of which is presented in Table 1, the fertilizers were applied to three-row plots, the middle row of which was used for stem-rot and yield determinations. The analysis of the fertilizers used was as follows: Sodium nitrate, 15 per cent; ammonium sulphate, 20 per cent; superphosphate, 16 per cent, and muriate of potash, 50 per cent. The fertilizers were applied after seeding rather than at seeding time, since the results of fertilizer work conducted by the College's Agronomy Department at the Rice Branch Station indicated that such a procedure would give greater increases in yield. The plots were drained be-

fore the applications were made and were reflooded in one week. The results from fertilizers applied July 17 indicate that potassium is the important element to consider in a fertilizer program designed to retard the development of stem rot. No response was obtained, as shown by the stem-rot indices, when the fertilizers were applied as late as August 10. Because of the unevenness of the rice stand in the various plots, the yield results are by no means conclusive; however, they suggest substantial increases as a result of the nitrogen and phosphorus applications.

Since favorable results were obtained in 1936, three additional experiments were conducted in 1937 at three different locations at the Rice Branch Station. In the first experiment various fertilizers were applied, at the rates and dates shown in Table 2, to 1/100-acre plots. The indices were, for the most part, too low for accurate comparisons; however, they show that stem-rot severity was greatly increased in the plots where nitrogen and phosphorus were applied in combination. The low yields were caused largely by the excessive grass on the plots, and as pointed out previously, low-yielding rice is ordinarily not severely attacked by stem rot. In the second experiment the fertilizers were applied at higher rates to relatively uniform 3-foot square plots, enclosed with galvanized tin levees. Heretofore, no attempt had been made to separate the different plots with levees. The results,

TABLE 3. EFFECT OF FERTILIZERS ON STEM ROT AND YIELD OF EARLY PROLIFIC RICE AT RICE BRANCH EXPERIMENT STATION, 1937

No.	Treatment[1]	Rate per acre	Stem-rot index[2]	Acre yield[2]
		Pounds		*Bushels*
1	Ammonium sulphate	360	42.8	52.16
2	Superphosphate	600	32.1	50.73
3	Potassium sulphate	140	28.6	39.12
4	Ammonium sulphate Superphosphate	360 600	44.7	59.03
5	Ammonium sulphate Potassium sulphate	360 140	33.9	45.76
6	Superphosphate Potassium sulphate	600 140	20.7	49.31
7	Ammonium sulphate Superphosphate Potassium sulphate	360 600 140	24.7	65.67
8	Check	0	28.9	40.54

[1] Fertilizers applied July 9. [2] Averages of four replicates.

presented in Table 3, show that the various applications resulted in significant differences between indices and between yields. The indices were increased, as compared to the checks, by nitrogen and phosphorus when applied separately or in combination; but when potassium was applied alone or in combination with nitrogen and phosphorus the indices were comparable to or sometimes below those of the check. From the standpoints of yield as well as dis-

TABLE 4. EFFECT OF FERTILIZERS ON STEM ROT AND YIELD OF RICE AT RICE BRANCH EXPERIMENT STATION, 1937

Treatment[1]	Rate per acre	Stem-rot index[2]	Yield per acre[2]
	Pounds		*Bushels*
Ammonium sulphate	180	64	50
Superphosphate	300	59	53
Potassium sulphate	70	55	54
Ammonium sulphate Superphosphate	80 300	66	54
Ammonium sulphate Potassium sulphate	80 70	53	59
Superphosphate Potassium sulphate	300 70	60	57
Ammonium sulphate Superphosphate Potassium sulphate	180 300 70	60	59
Check	0	57	45

[1] Applied July 9. [2] Average of four replicates.

ease control, treatment No. 7, in which a complete fertilizer was added, gave the best results. The use of the small, enclosed plots in this experiment made it possible to obtain more uniform disease infection than was obtained in the previous experiments.

The third experiment, conducted in 1937, was similar to the one reported in Table 3, with the exception that the fertilizer rates were reduced by one-half. The results presented in Table 4 relative to the disease indices, although not as outstanding, are in general agreement with those given in Table 3. The differences in yields were not significant, because of large variations in similarly treated plots. The work in 1937 showed that variable results may be expected at different locations.

The studies in 1938 were designed to determine the effect of various rates of potassium sulphate, alone and in complete fer-

TABLE 5. EFFECT OF FERTILIZERS ON STEM ROT AND YIELD OF RICE VARIETIES, RICE BRANCH EXPERIMENT STATION, 1938

Treatment per acre [1]	Stem-rot indices [2]						Yields per acre [2]				
	Supreme Blue Rose	Zenith	Calora	Fortuna	Nira	Average	Supreme Blue Rose	Zenith	Calora	Fortuna	Average
Applied at planting time:							*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
600 lbs. 6-8-12	29	34	25	51	57	39.2	62	50	61	72	61.2
600 lbs. 6-0-12	27	29	27	54	44	36.2	66	41	60	61	57.0
600 lbs. 0-0-12	27	34	31	45	54	38.2	67	43	55	65	57.5
Applied 2 months after planting:											
600 lbs. 0-0-12	22	33	29	46	54	36.8	63	42	51	61	54.2
600 lbs. 0-0-6	25	37	32	49	55	39.6	64	54	49	66	58.2
300 lbs. 6-8-6	25	35	36	53	55	40.8	65	44	54	71	58.5
300 lbs. 6-8-12	29	34	32	52	57	40.8	64	42	63	63	58.0
300 lbs. 6-8-24	27	36	28	53	53	39.4	75	55	56	64	62.5
600 lbs. 6-8-6	25	36	30	49	56	39.2	66	53	65	76	65.0
600 lbs. 6-8-12	31	34	25	53	57	40.0	68	49	58	76	62.7
600 lbs. 6-8-24	27	30	25	51	57	38.0	69	56	66	71	65.5
Check	32	29	35	50	62	41.6	58	50	54	62	56.0
Average	27.2	33.4	29.6	50.5	55.1		65.6	48.2	57.7	67.3	

[1] N=ammonium sulphate; P=superphosphate; K=potassium sulphate.
[2] Averages of four replicates.

tilizers, on the development of stem rot on different rice varieties. The fertilizers were applied at the rates and dates specified in Table 5 to 3-foot square plots enclosed with soil levees. The border effects of the soil levees obviously reduced the benefits of the fertilizers in this experiment. Nevertheless, the results show that comparatively large applications of nitrogen and phosphorus can be made in combination with potassium without significantly increasing the amount of stem rot. There was a significant difference in the response of varieties to stem rot, but no conclusion can be drawn from the results relative to the response of the varieties to the different treatments as measured by the disease indices.

In 1938, fertilizers were applied on two rice farms, one near Almyra and the other near DeWitt, on which severe lodging, caused by stem rot, had occurred the preceding year. Applications were made on yard-square plots, and no attempt was made to separate the plots with levees. The fertilizers were applied in the irrigation water rather than to drained plots as in previous experiments, and this probably accounts for the small differences obtained from the various treatments. (See Tables 6 and 7.) On the Shire farm near Almyra, 600 pounds of 6-8-24 fertilizer appeared to reduce the amount of lodging, while on the Garot farm, near DeWitt, the lowest index was obtained with 600 pounds of

TABLE 6. EFFECT OF FERTILIZERS ON STEM ROT OF SUPREME BLUE ROSE RICE, SHIRE FARM, ALMYRA, 1938

Treatment per acre [1]	Stem-rot index [2]	Plants lodged [2]	Yield per acre [2]
Applied 2 months after planting:		*Number*	*Bushels*
300 lbs. 6-8-6	76	65	37
300 lbs. 6-8-12	71	51	38
300 lbs. 6-8-24	77	64	40
600 lbs. 6-8-6	73	49	40
600 lbs. 6-8-12	71	48	39
600 lbs. 6-8-24	64	32	41
600 lbs. 0-0-6	78	71	36
600 lbs. 0-0-12	70	44	38
600 lbs. 0-0-24	64	36	38
Check	77	62	40

1 N=ammonium sulphate; P=superphosphate; K=potassium sulphate.
2 Average of four replicates.

0-0-12 fertilizer. Results of additional outlying plot work should offer a basis for sounder disease-control recommendations.

TABLE 7. EFFECT OF FERTILIZERS ON STEM ROT OF NIRA RICE, GAROT FARM, DEWITT, 1938

Treatment per acre [1]	Stem rot index [2]	Yield per acre [2]
Applied 2 months after planting:		*Bushels*
600 lbs. 0-0-12	22	53
300 lbs. 6-8-6	36	58
300 lbs. 6-8-12	26	56
600 lbs. 6-8-24	27	56
Check	27	51

[1] N=ammonium sulphate; P=superphosphate; K=potassium sulphate.
[2] Average of four replicates.

Greenhouse studies. Since the results of field experiments varied considerably at different locations because of soil variability, two supplementary experiments were conducted in the greenhouse where more uniform conditions could be established. The purpose of the first experiment was to determine the effect of various rates of potash in a complete fertilizer on the development of the disease. Soil from the Rice Branch Station was thoroughly mixed and placed in 3-gallon jars at the rate of 8 kilograms per jar. Ten plants were grown in each jar. At 8 and 10 weeks after planting, the rice was drained, fertilized according to the plan presented in Table 8, and reflooded one week later. In general, yields increased as the rates of nitrogen and phosphorus applications increased, but they were not influenced by the applications of potassium. The disease indices uniformly decreased as the amount of potassium in the fertilizer increased, but only when the largest applications of complete fertilizer were made; that is, 1,200 pounds per acre.

In the second experiment a sand culture technique was used to study the effect of interactions of different levels of nitrogen, phosphorus, and potassium on the development of stem rot. Three-gallon jars with side-bottom drains were filled with sand to within 3 inches of the tops. The jars were equipped with No. 3 one-hole rubber stoppers and L-shaped glass tubes, so that the level of the solution could be held 2 inches above the surface of the sand. The glass tubes were placed on the outside of

TABLE 8. EFFECT OF FERTILIZERS ON STEM ROT OF SUPREME BLUE ROSE RICE GROWN IN GREENHOUSE, NOVEMBER 11, 1937, TO APRIL 5, 1938

Treatment per acre [1]	Stem rot index [2]	Yield [3]
Applied 8 weeks after planting:		*Grams*
300 lbs. 6-8-6	55	12
300 lbs. 6-8-12	53	12
300 lbs. 6-8-24	39	8
600 lbs. 6-8-6	55	13
600 lbs. 6-8-12	44	12
600 lbs. 6-8-24	50	12
1,200 lbs. 6-8-6	43	13
1,200 lbs. 6-8-12	35	14
1,200 lbs. 6-8-24	29	15
Applied 10 weeks after planting:		
300 lbs. 6-8-6	53	8
300 lbs. 6-8-12	40	6
300 lbs. 6-8-24	61	8
600 lbs. 6-8-6	51	10
600 lbs. 6-8-12	55	12
600 lbs. 6-8-24	58	13
1,200 lbs. 6-8-6	44	23
1,200 lbs. 6-8-12	42	23
1,200 lbs. 6-8-24	36	21
No treatment	48	7

[1] N=ammonium sulphate: P=superphosphate: K=muriate of potash.
[2] Average of four replicates.
[3] Average of three replicates.

the jars so that they could be rotated from the vertical to a horizontal position to drain the solutions. The stock solutions were made up as follows:

KCl	20.0 grams to 2 liters
$MgSO_4 2H_2O$	120.0 grams to 2 liters
$(NH_4)_2SO_4$	140.0 grams to 2 liters
$Ca(H_2PO_4)_2 2H_2O$	29.5 grams to 2 liters
$CaCl_2 2H_2O$	140.0 grams to 2 liters
$FeCl_3 6H_2O$	8.0 grams to 2 liters

To obtain the desired concentrations the number of milliliters of stock solutions added to 12 liters of tap water were:

Solution No.	$(NH_4)_2SO_4$	KCl	$MgSO_4$	$Ca(H_2PO_4)_2$	$CaCl_2$	$FeCl_3$	B Zn Cu Mn
1	15.0	2.5	10	50	5	10	Trace
2	15.0	50.0	10	50	5	10	Trace
3	15.0	100.0	10	50	5	10	Trace
4	37.5	2.5	10	100	0	10	Trace
5	37.5	2.5	10	1	10	10	Trace
6	6.0	2.5	10	100	0	10	Trace
7	6.0	100.0	10	1	10	10	Trace
8	6.0	100.0	10	50	5	10	Trace
9	15.0	100.0	10	1	10	10	Trace
10	37.5	100.0	10	100	0	10	Trace

Three liters of each solution was added to each of four replicates. The jars were drained and the solutions renewed twice a week. The solutions were all adjusted to pH 6.5, at the time of application; however, no attempt was made to maintain this pH after the solutions were applied. Ten plants were grown in each jar. The plants were inoculated 2 months after the rice was planted with sclerotia, which were produced in rice straw under aseptic conditions.

The results of the experiment offer further confirmatory evidence that the losses caused by stem rot are influenced by host nutrition (Table 9). With solutions 1, 2, and 3, in which the nitrogen and phosphorus levels were held constant, the disease indices decreased as the potassium level was increased. With solutions 4 and 5, in which the nitrogen level was high and the potassium level low, high indices as well as severe lodging were obtained. With solutions 6, 7, and 8, in which the nitrogen level was low, comparatively low indices were obtained regardless of whether the potassium level was high or low. With solutions 9 and 10, in which the potassium level was constant, the index increased as the nitrogen was increased. The low, medium, and high levels of phosphorus had practically no differential effect on the development of the disease.

The various solutions had a marked effect on plant growth. The plants grown in solutions 1, 2, and 3 had a good color and an average height of 42, 45, and 45 inches, respectively. Plants grown

in solutions 4 and 5 had an abnormally dark green color, weak culms, and an average height of 45 and 33 inches, respectively. Plants grown in solutions 6, 7, and 8 had a light green color, and were severely stunted, having an average height of 32, 34, and 32 inches, respectively. Plants grown in solution 9 were normal in color and had an average height of 45 inches, while the plants grown in solution 10 were dark green in color and had an average height of 45 inches. The glumes on the panicles of the plants grown in the solutions containing high nitrogen, (treatments 4, 5 and 12), were noticeably darker in color than the glumes on the panicles of plants grown in the other solutions. Wide variations in yields were obtained as shown in Table 9.

TABLE 9. RELATIONSHIP OF HOST NUTRITION TO SEVERITY OF STEM ROT ON EARLY PROLIFIC RICE GROWN IN GREENHOUSE, 1938

Solution No.	Concentration of solution			Stem rot index [1]	Plants lodged [1]	Yield [1]
	N	P	K			
	Level	*Level*	*Level*		*Number*	*Grams*
1	Medium	Medium	Low	44.5	0	14.9
2	Medium	Medium	Medium	23.3	0	16.6
3	Medium	Medium	High	18.6	0	16.3
4	High	High	Low	70.7	12	14.2
5	High	Low	Low	70.3	7	7.0
6	Low	High	Low	26.8	0	3.5
7	Low	Low	High	23.8	0	4.2
8	Low	Medium	High	22.4	0	3.0
9	Medium	Low	High	24.4	0	19.6
10	High	High	High	41.0	0	19.6

[1] Average of four replicates.

CONCLUSION

Considering the field data as a whole, some interesting facts were determined relative to the effect of fertilizers on the severity of stem rot and the yield of rice. Nitrogen, when applied in sufficient quantities, significantly increased yields as well as the disease indices. (A high disease index signifies severe disease infection.) Phosphorus applications, in general, produced moderate increases in yield and tended to increase the stem-rot indices; however, the increases in either case were not as great as those

induced by the nitrogen applications. Nitrogen and phosphorus applications, for the most part, produced higher yields and indices when applied in combination than when applied separately. Potash applications were, in general, only slightly beneficial in increasing yields. However, potassium when applied alone did not increase the disease indices, and when applied in combination with nitrogen and phosphorus was instrumental in maintaining the indices on a level equal to or sometimes below those of the check plots. Consequently, it appears that in a fertilizer program designed to improve yields on stem-rot infested land, sufficient potassium should be added to the fertilizer to minimize the losses that might be caused by stem rot.

The results of greenhouse experiments in general support the results obtained in the field. Of particular interest is the fact that, using a sand culture technique, very high disease indices were obtained when the plants were grown in unbalanced solutions, high in nitrogen and low in potassium. With solutions in which the nitrogen and phosphorus levels were held constant, stem-rot severity decreased as the potassium level in the solution was increased.

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